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(54) **FLAT STRAIN WAVE GEAR DEVICE**

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(73) Proprietor: **Harmonic Drive Systems Inc.**
Shinagawa-ku
Tokyo 140-0013 (JP)

(72) Inventor: **KOBAYASHI, Masaru**
Azumino-shi, Nagano 399-8305 (JP)

(74) Representative: **Schmitt-Nilson Schraud Waibel
Wohlfrom**
Patentanwälte Partnerschaft mbB
Pelkovenstraße 143
80992 München (DE)

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JP-A- S60 132 155 JP-U- S6 389 453

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Description

TECHNICAL FIELD

[0001] The present invention relates to a strain wave gearing, and in particular relates to a flat strain wave gearing that has a short axial length and that is configured such that a flexible gear facing a rigid gear in the axial direction is caused to flex in the axial direction and partially mesh with the rigid gear.

BACKGROUND ART

[0002] In strain wave gearings having a "cup" profile, which are the mainstream form of strain wave gearings, a flexible gear having external teeth that are parallel to the axial direction is flexed in an ellipsoidal shape by a wave generator. The flexible gear that has been flexed in the ellipsoidal shape meshes with internal teeth of a rigid gear that is disposed on the radially outer side thereof at locations on and near the long axis of the ellipsoidal shape in a state of meshing that is substantially parallel to the axial direction. Strain wave gearings having a "cup" profile are superior to those having a "pancake" profile (strain wave gearings having a "flat" profile), which have a short axial-direction length, and to those having a "short-barrel" profile, in which the axial length is reduced, in terms of torque capacity and transmission characteristics.

[0003] However, in order to leverage the characteristics of strain wave gearings having a "cup" profile, the axial length thereof must be equal to or greater than a given length. Specifically, the axial length is determined according to the tooth width of the flexible gear and the lengths of a barrel part and a diaphragm of the flexible gear, and is difficult to flatten. Employing a configuration in which the flexible gear and the rigid gear are caused to face each other in the axial direction and in which the two gears are caused to mesh in the axial direction in order to flatten such strain wave gearings is a measure that has been considered.

[0004] In the prior art, Patent Documents 1 to 5 propose strain wave gearings having configurations in which a flexible gear and a rigid gear are caused to mesh in the axial direction. For example, in the strain wave gear mechanisms disclosed in Patent Documents 1 and 2, a rigid gear and a flexible gear are caused to face each other in the axial direction, and the flexible gear is caused to flex in the axial direction and partially mesh with the rigid gear. A wave generator for flexing the flexible gear in the axial direction is provided with a configuration in which the back surface of the flexible gear is supported by a rigid cam plate in the axial direction via balls.

PRIOR-ART DOCUMENTS

PATENT DOCUMENTS

[0005]

Patent Document 1: JP S48-69947 A
 Patent Document 2: JP S60-40845 A
 Patent Document 3: JP S60-129455 A
 Patent Document 4: JP H04-370445 A
 Patent Document 4: EP 0 148 809 A2

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] Strain wave gearings having configurations in which a rigid gear and a flexible gear are caused to face each other in the axial direction and in which the flexible gear is caused to flex in the axial direction and mesh with the rigid gear are effective in reducing axial length. However, in order to ensure torque capacity and transmission characteristics similar to those in the case of strain wave gearings having a "cup" profile, the tooth width of the flexible gear and the length of the diaphragm must be equal to or greater than a prescribed length, and to ensure a prescribed ease of flexing, a suitable meshing state must be formed between the two gears at each position in the tooth trace direction. In addition, the rigidity with which the flexible gear is supported by the wave generator in the axial direction must be improved.

[0007] In view of the foregoing, it is an object of the present invention to provide a flat strain wave gearing provided with a flexible gear that is capable of meshing with a rigid gear in the axial direction in a suitable state, and a wave generator that has high supporting rigidity.

MEANS OF SOLVING THE PROBLEMS

[0008] In order to achieve the above object, the flat strain wave gearing of the present invention has: a rigid gear in which first teeth are formed, at a uniform pitch in the circumferential direction, on an end surface that is orthogonal to the axial direction; a flexible gear, which faces the rigid gear in the axial direction and in which second teeth that are capable of meshing with the first teeth in the axial direction are formed at a uniform pitch in the circumferential direction; and a wave generator that causes a tooth formation portion of the flexible gear where the second teeth are formed to flex in the axial direction, the second teeth to mesh with the first teeth at a plurality of positions set apart in the circumferential direction, and the positions where the two gears mesh to move in the circumferential direction. The flexible gear is formed in a shape that follows a flat truncated-cone shape having a vertex angle of at least 165° and less than 180°, and moreover is provided with: a rigid boss; a diaphragm that has a bellows-form cross-section, the diaphragm expanding from the outer peripheral edge of the rigid boss outward and toward a direction away

from the rigid gear; and a conical barrel part, which is continuous with the outer peripheral edge of the diaphragm and expands outward and toward a direction away from the rigid gear, and on which the tooth formation portion is formed.

[0009] The flat strain wave gearing of the present invention is formed in a flat truncated-cone shape having a vertex angle of at least 165° and less than 180° . The outer-peripheral-edge-side outer peripheral surface portion of the cone surface thereof is a tooth formation portion where the second teeth are formed. The tooth formation portion is connected to the rigid boss, which is an output shaft fastening part, via the diaphragm having the bellows-form cross-section. It is possible to ensure ease of axial-direction flexing of the tooth formation portion and cause the second teeth to satisfactorily mesh with the first teeth at each position in the tooth trace direction. It is also possible to suppress any local deviation in load torque of tooth meshing parts in the tooth formation portion.

[0010] In the present invention, the wave generator is provided with a rigid cam plate in which is formed a cam surface that functions as a roller raceway surface facing the inner-peripheral surface of the tooth formation portion of the conical barrel part in the axial direction, a plurality of cylindrical rollers that are mounted between the cam surface of the rigid cam plate and the inner peripheral surface of the flexible gear, and an annular retainer that retains the plurality of cylindrical rollers at uniform intervals in the circumferential direction. The circumferential-direction curved shape of the cam surface is regulated such that the axial-direction position of the plurality of cylindrical rollers rolling in the circumferential direction along the cam surface undulates a plurality of times at uniform amplitude in the axial direction while the plurality of cylindrical rollers complete one cycle along the cam surface. The retainer of the wave generator has flexibility in the axial direction. The retainer consists of a plurality of modules being linked in the circumferential direction. Each module is linked to the modules adjacent thereto in a rotatable state relative to the adjacent modules about a radius line passing through a center of the retainer.

[0011] The roller raceway surface is formed in a curve that is perpendicular to the axial direction, or is formed in a curve that emulates a curved shape obtained in a flexed state in which the tooth formation portion of the flexible gear is flexed in the axial direction. The retainer of the wave generator is also capable of flexing in the axial direction. The retainer is provided with flexibility such that the retainer can track axial-direction displacement of the roller raceway surface produced in association with rotation of the wave generator, axial-direction displacement of the cylindrical rollers rolling along the roller raceway surface, and axial-direction displacement of the tooth formation portion of the flexible gear that is flexed by the wave generator.

[0012] The second teeth are thereby supported at each position in the tooth trace direction from a direction that

follows the axial direction. Thus, the rigidity with which the flexible gear is supported by the wave generator is high. The second teeth of the flexible gear also can form a state of meshing with the first teeth of the rigid gear in the axial direction at each position in the tooth trace direction, and the torque transmission characteristics of the second teeth can be improved.

[0013] In an embodiment, the flat strain wave gearing further comprises a cylindrical housing in which the rigid gear, the flexible gear, and the wave generator are assembled; an output shaft coaxially fixed to the rigid boss of the flexible gear; a first bearing, in particular a cross-roller bearing, that is disposed between the housing and the output shaft and that supports the output shaft in a state that allows rotation with respect to the housing; and a second bearing, in particular a thrust roller bearing, that is disposed between the housing and the rigid cam plate of the wave generator and that supports the rigid cam plate in the axial direction in a state that allows rotation with respect to the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

FIG. 1(a) is a schematic end-surface view of a flat strain wave gearing according to an embodiment of the present invention, and FIGS. 1(b) and 1(c) are schematic longitudinal cross-sectional views of the same;

FIG. 2(a) is a plan view showing a flexible gear, FIG. 2(b) is a cross-sectional view showing the flexible gear before the same is flexed, and FIGS. 2(c) and 2(d) are cross-sectional views of the flexible gear in a flexed state;

FIG. 3(a) is an explanatory diagram showing a rigid cam plate, and FIGS. 3(b1), 3(b2), 3(c1), and 3(c2) are cross-sectional views showing examples of cam surface profiles;

FIG. 4(a) is a plan view showing a retainer, and FIG. 4(b) is a perspective view showing a module of the same;

FIGS. 5(a) and 5(b) are schematic longitudinal cross-sectional views showing a unit-type flat strain wave gearing according to an embodiment of the present invention; and

FIGS. 6(a1) to 6(a3) are explanatory diagrams showing flexible gears that have different diaphragm shapes, and FIG. 6(b) is a list table showing results of comparative experiments.

MODE FOR CARRYING OUT THE INVENTION

[0015] An embodiment of a flat strain wave gearing to which the present invention is applied is described below with reference to the accompanying drawings.

(Flat strain wave gearing)

[0016] FIG. 1(a) is a schematic end-surface view of a flat strain wave gearing according to an embodiment of the present invention, FIG. 1(b) is a schematic longitudinal cross-sectional view showing a portion sectioned at a line 1b-1b' of FIG. 1(a), and FIG. 1(c) is a schematic longitudinal cross-sectional view showing a portion sectioned at a line 1c-1c' of FIG. 1(a). The flat strain wave gearing 1 is provided with a rigid gear 2, a flexible gear 3 that is formed to have a flat truncated-cone shape, and a wave generator 4. The wave generator 4 causes the flexible gear 3 to flex in the direction of a central axis 1a (axial direction) and mesh with the rigid gear 2 at a plurality of positions that are set apart in the circumferential direction.

[0017] The rigid gear 2 is provided with an annular member 21 of uniform thickness, and first teeth 23 that are formed on one annular end surface 22 of the annular member 21. The annular member 21 is centered on the central axis 1a and is disposed perpendicularly with respect to the central axis 1a. The first teeth 23 are formed on the annular end surface 22 at a uniform pitch in the circumferential direction centered on the central axis 1a, and the tooth trace direction of the first teeth 23 is the radial direction.

[0018] The flexible gear 3 is provided with a rigid boss 31, a diaphragm 32 having a bellows-form cross-section, a conical barrel part 33, and second teeth 35 formed on an outer-peripheral-edge-side tooth formation portion 34 of the conical barrel part 33. The second teeth 35 are formed on the conical tooth formation portion 34 at a uniform pitch in the circumferential direction centered on the central axis 1a. The tooth trace direction of the second teeth 35 is the generatrix direction of the conical outer peripheral surface.

[0019] The wave generator 4 is provided with a rigid cam plate 41 having a disc shape, a plurality of cylindrical rollers 42, and an annular retainer 43 that retains the cylindrical rollers 42 at uniform intervals in the circumferential direction in a state that allows rolling. The wave generator 4 causes the tooth formation portion 34 of the flexible gear 3 to flex in the axial direction and the second teeth 35 to mesh with the first teeth 23 at a plurality of positions that are set apart in the circumferential direction. The rigid cam plate 41 is centered on the central axis 1a and is disposed perpendicularly with respect to the central axis 1a. The rigid cam plate 41 is disposed on the side of the flexible gear 3 that is opposite from the rigid gear 2 in the axial direction. An outer-peripheral-edge-side portion of an end surface 44 on the flexible-gear 3 side of the rigid cam plate 41 is a cam surface 45 of uniform width that extends in the circumferential direction. The cam surface 45 functions as a roller raceway surface for the cylindrical rollers 42 and faces a conical inner peripheral surface portion 36, which is the back surface of the tooth formation portion 34 of the flexible gear 3.

[0020] The flat strain wave gearing 1 is assembled in a mechanism subject to assembly, as shown by virtual lines in FIGS. 1(b) and 1(c). A rotary input shaft 5 is coaxially linked to the rigid cam plate 41 of the wave generator 4. The rotary input shaft 5 is, e.g., a motor rotary shaft. The rigid cam plate 41 is supported in a state that allows rotation by a cylindrical housing 6, which is a fixed-side member in the mechanism subject to assembly. For example, thrust roller bearings 7 are mounted between the back surface of the rigid cam plate 41 and an end surface 6a of the housing 6 that faces the back surface, and the rigid cam plate 41 is supported by the housing 6 in the axial direction in a state that allows rotation. Furthermore, the rigid gear 2 is coaxially fixed to the housing 6. By contrast, a rotary output shaft 8 or other load-side member is coaxially linked to the rigid boss 31 of the flexible gear 3.

[0021] The rigid cam plate 41 is assembled so as to attain a state in which a prescribed pre-pressure is applied in a direction from the rotary-input-shaft 5 side toward the flexible gear 3. When the rigid cam plate 41 rotates at high speed due to the rotary input shaft 5, the tooth formation portion 34 is repeatedly displaced in the axial direction by the cam surface 45. At positions at which the tooth formation portion 34 is displaced in the axial direction by a maximum displacement amount, the second teeth 35 of the tooth formation portion 34 mesh with the first teeth 23 of the rigid gear 2 in the axial direction.

[0022] In the present example, as shown in FIG. 1(b), the tooth formation portion 34 is displaced in the axial direction by the maximum displacement amount at two positions that are set apart by 180° in the circumferential direction, and the second teeth 35 mesh with the first teeth 23 of the rigid gear 2 at these two positions. At positions obtained by rotating 90° from the aforementioned two positions, the second teeth 35 are set apart from the first teeth 23 in the axial direction, as shown in FIG. 1(c). In this instance, the difference between the numbers of first and second teeth 23, 35 is equal to $2n$. For example, the number of second teeth 35 is two less than the number of first teeth 23. When the wave generator 4 makes one rotation, the rigid gear 2 and the flexible gear 3 undergo relative rotation by an angular amount corresponding to the difference between the numbers of teeth. In association with rotation of the wave generator 4, the flexible gear 3 rotates at a rotation speed that is greatly reduced in accordance with the difference between the numbers of teeth of the rigid gear 2 and the flexible gear 3. The reduced rotation is extracted from the rigid boss 31 of the flexible gear 3 by the rotary output shaft 8.

[0023] FIG. 2(a) is a plan view showing the flexible gear, FIG. 2(b) is a cross-sectional view showing the flexible gear in a state before the same is flexed, FIG. 2(c) is a cross-sectional view of the flexible gear in a flexed state at a portion that is sectioned at a line 2c-2c', and FIG. 2(d) is a cross-sectional view of the flexible gear

in a flexed state at a portion that is sectioned at a line 2d-2d'.

[0024] In an initial state before being flexed, the flexible gear 3 overall has a flat truncated-cone shape centered on the central axis 1a, as shown in FIG. 2(b). For example, the flexible gear 3 has a flat truncated-cone shape having a vertex angle of at least 165° and less than 180°. The rigid boss 31 of the flexible gear 3 has a disc shape of uniform thickness. The diaphragm 32, which has a bellows-form cross-section, expands radially outward in a cone shape from the circular outer peripheral edge of the rigid boss 31. The conical barrel part 33 expands radially outward in a cone shape from the circular outer peripheral edge of the diaphragm 32. The second teeth 35 are formed on the outer peripheral surface of the tooth formation portion 34 of the conical barrel part 33 at a uniform pitch in the circumferential direction. The second teeth 35 of the flexible gear 3 can mesh with the first teeth 23 of the rigid gear 2 and face the first teeth 23 in the axial direction (the direction of the central axis 1a).

[0025] The diaphragm 32 is provided with a first curved portion 32a that protrudes in a semi-circular shape from the outer peripheral edge end of the rigid boss 31 toward one side in the axial direction, and a second curved portion 32b that is continuous with the first curved portion 32a and that protrudes in a semi-circular shape toward the other side in the axial direction. The end of the second curved portion 32b is curved radially outward and is connected to the conical barrel part 33. The cross-section of an attachment portion 31a of the rigid boss 31 attaching to the first curved portion 32a is cut out in a semi-circular shape, the plate thickness of the attachment portion gradually increasing from the diaphragm 32 side toward the rigid-boss 31 side.

[0026] In a state before being flexed by the wave generator 4, the tooth formation portion 34 of the flexible gear 3 is positioned at an axial-direction position p0 as shown in FIG. 2(b). In a state where the tooth formation portion 34 is flexed by the wave generator 4, the tooth formation portion 34 is flexed in the axial direction as shown in FIGS. 2(c) and 2(d). Specifically, the angular positions at which the tooth formation portion 34 is flexed in the axial direction by the maximum displacement amount are angular positions that are set apart by 180° in the circumferential direction, as shown in FIG. 2(c). At these angular positions, the tooth formation portion 34 of the flexible gear 3 is displaced from the initial position p0 to a position p1 at which the tooth formation portion 34 is flexed toward the rigid-gear 2 side by a maximum displacement amount Δ_{max} . The second teeth 35 thereby mesh with the first teeth 23 of the rigid gear 2. However, at angular positions obtained by rotating 90° from the angular positions having the maximum displacement amount Δ_{max} , the tooth formation portion 34 is located at a position p2 that is displaced by a very small amount in the opposite axial direction, as shown in FIG. 2(d). At these positions, the amount of axial-direction displacement caused by the wave generator 4 is substantially

zero, and the second teeth 35 are set apart from the first teeth 23.

[0027] The inventors experimented on the flexible gear 3 with respect to, *inter alia*, ease of flexing when the cross-sectional shape of the diaphragm 32 is changed. One example of experimental results is described below with reference to FIG. 6. The tooth formation portion was flexed in the axial direction by a maximum displacement amount (displacement amount 1) at positions that were set apart by 180° when the following diaphragms were provided: a diaphragm (shape FS1) having a cross-sectional shape that is circularly curved outward in the radial direction from the outer peripheral edge of the rigid boss with small curvature, as shown in FIG. 6(a1); a diaphragm (shape FS2) having a cross-sectional shape that is curved with greater curvature, as shown in FIG. 6(a2); and a diaphragm (shape FS3) having the bellows-form cross-sectional shape according to the present example shown in FIG. 6(a3). The displacement reaction force, the maximum stress produced in the diaphragm, and the warping amount in the opposite axial direction (displacement amount 2) at positions obtained by rotating 90° from the positions having the maximum displacement amount were measured for each case.

[0028] The measurement results are shown in a table in FIG. 6(b). In the table, the displacement reaction force, the maximum stress, the displacement amount 1, the displacement amount 2, and the total of the displacement amounts 1 and 2 for the shape FS1 are each depicted as reference unit amounts of "1" for the purpose of comparison. From the table, it is understood that, in the flexible gear 3 provided with the diaphragm having the bellows-form cross-section of the present example (shape FS3), it is possible to maintain ease of flexing and suppress any local deviation in torque of tooth meshing parts to a greater extent than when the invention is provided with a diaphragm having another shape.

[0029] FIG. 3(a) is an explanatory diagram showing the rigid cam plate 41 of the wave generator 4, FIGS. 3(b1) and 3(b2) are cross-sectional views showing examples of cam surface profiles at a portion that is sectioned at a line 3b1-3b1', and FIGS. 3(c1) and 3(c2) are cross-sectional views showing examples of cam surface profiles at a portion that is sectioned at a line 3c1-3c1'.

[0030] The cam surface 45 formed on the rigid cam plate 41 of the wave generator 4 has a curve that is perpendicular to the central axis 1a. The cam surface 45 is formed in a curved shape toward the circumferential direction, as shown in FIG. 3(a), and is such that, for example, the axial-direction position of the surface is displaced in the form of a sine wave. Specifically, the circumferential-direction curved shape of the cam surface 45 of the rigid cam plate 41 is regulated such that the axial-direction position of the cylindrical rollers 42 rolling along the cam surface 45 undulates a plurality of times at uniform amplitude (maximum displacement amount) in the axial direction while the cylindrical rollers 42 complete one cycle along the cam surface 45. In the present

example, the circumferential-direction curved shape of the cam surface 45 is set such that the cylindrical rollers 42 undulate twice in the axial direction while completing one cycle along the cam surface 45. In the cam surface 45, the angular positions at which the tooth formation portion 34 of the flexible gear 3 is flexed in the axial direction by the maximum displacement amount are the positions of 0° and 180° shown in FIG. 3(a). At the angular positions of 90° and 270°, which are set apart from the aforementioned positions by 90°, axial-direction displacement is not applied to the tooth formation portion 34.

[0031] The cam surface 45 has a curve that is perpendicular to the central axis 1a at each position in the circumferential direction, as shown in FIGS. 3(b1) and 3(c1). However, a cam surface provided with a curve that, at each position in the circumferential direction, emulates the shape of the inner peripheral surface portion 36, which is the back surface of the tooth formation portion 34 of the flexible gear 3, in an axially flexed state can also be used as the cam surface 45. The flexed state of the tooth formation portion 34 is a state in which the tooth formation portion 34 is flexed in the axial direction by the maximum displacement amount at positions that are set apart by 180° in the circumferential direction in a state where the rigid boss 31 of the flexible gear 3 is restrained so as not to move in the axial direction. For example, the cam surface 45 is an orthogonal surface that is orthogonal to the central axis 1a at the angular positions of 0° and 180° (positions with maximum displacement amount), as shown in FIG. 3(b2), and the cam surface 45 is an inclined surface that is inclined relative to a direction perpendicular to the central axis 1a at the angular positions of 90° and 270° (positions with minimum displacement amount), as shown in FIG. 3(c2). Between the orthogonal surface shown in FIG. 3(b2) and the inclined surface shown in FIG. 3(c2), the cam surface is set such that the angle of inclination gradually increases from the orthogonal surface toward the inclined surface.

[0032] The retainer 43 of the wave generator 4 is described below with reference to FIG. 4. FIG. 4(a) is a plan view showing the retainer 43, and FIG. 4(b) is a perspective view showing a module of the same. The retainer 43 is disposed between the cam surface 45 of the rigid cam plate 41 and the inner peripheral surface portion 36 of the flexible gear 3. The cylindrical rollers 42 are retained in pockets 43a formed in the retainer 43 in an orientation such that roller center lines face the radial direction. It is desirable for 17 or more cylindrical rollers 42 to be disposed. The cylindrical rollers 42 retained by the retainer 43 in a state that allows rolling are retained between the cam surface 45 and the inner peripheral surface portion 36 in a state in which a prescribed pre-pressure is applied from the axial direction. The retainer 43 in the present example is configured by arc-shaped modules 46 being linked in the circumferential direction.

[0033] As shown in FIG. 4(b), one module 46 is provided with a fan-shaped body plate 461 that spreads at a

uniform angle, linking arc plates 462, 463 that protrude in the circumferential direction from the outer peripheral edge and the inner peripheral edge of one end surface of the body plate 461, and linking arc plates 464, 465 that protrude in the circumferential direction from the outer peripheral edge and the inner peripheral edge of the other end surface of the body plate 461. The outer peripheral surface shape of one outer-peripheral-side linking arc plate 464 is complementary to the inner peripheral surface shape of the other outer-peripheral-side linking arc plate 462. Similarly, the inner peripheral surface shape of one inner-peripheral-side linking arc plate 465 is complementary to the outer peripheral surface shape of the other inner-peripheral-side linking arc plate 463. Linking pins 466, 467 are formed integrally with the linking arc plates 464, 465 in a state of passing radially there-through. Pin holes 468, 469 into which the linking pins 466, 467 can be fitted are formed in the other linking arc plates 462, 463.

[0034] Linking the modules 46 in the circumferential direction forms rectangular pockets 43a between end surfaces 46a, 46b of the adjacent modules 46. The cylindrical rollers 42 retained in the pockets 43a are sandwiched between the inner-side end of the linking pin 466 and the outer-side end of the linking pin 467. Each module 46 is capable of turning relative to adjacent modules 46 about a radius line passing through the centers of the linking pins 466, 467. Therefore, the retainer 43 configured by the modules 46 being linked is capable of flexing in a shape that follows the cam surface 45 curved in the form of a sine wave along the circumferential direction, also is capable of flexing so as to track axial-direction displacement of the cylindrical rollers 42 rolling along the cam surface 45, and moreover is capable of flexing so as to track displacement of the tooth formation portion of the flexible gear 3 that is flexed in a shape following the cam surface 45. An annular molded article in which fiber-reinforced rubber or another elastic material is used can also be used as the retainer 43.

(Example of unit-type flat strain wave gearing)

[0035] FIG. 5(a) is a schematic longitudinal cross-sectional view showing a unit-type flat strain wave gearing according to an embodiment of the present invention, and FIG. 5(b) is a schematic longitudinal cross-sectional view showing a portion sectioned at a line 5b-5b'. The unit-type flat strain wave gearing 100 has a strain wave gear mechanism 10 provided with a rigid gear 2A, a flexible gear 3A, and a wave generator 4A. The flat strain wave gearing 100 also has a cylindrical housing 110 in which the strain wave gear mechanism 10 is incorporated, a rotary output shaft 120 that is coaxially secured to the flexible gear 3A, a first bearing, which is a cross-roller bearing 130, and a second bearing, which is thrust roller bearings 140.

[0036] The configuring elements of the strain wave gear mechanism 10 have the same configuration as

those of the flat strain wave gearing 1 shown in FIGS. 1-3. Thus, corresponding portions of the configuring elements (2A, 3A, 4A) in FIG. 5 are designated by the same symbols, and these corresponding portions are not described here.

[0037] The cross-roller bearing 130 of the unit-type flat strain wave gearing 100 is provided with an outer ring 131 that is coaxially fastened to one end of the housing 110, an outer ring raceway surface 132 formed in the inner peripheral surface of the outer ring 131, an inner ring raceway surface 133 formed in the circular outer peripheral surface of the rotary output shaft 120, and a plurality of cylindrical rollers 134 that are mounted between the outer ring raceway surface 132 and the inner raceway surface 133. The inner ring of the cross-roller bearing 130 is integrated with the rotary output shaft 120.

[0038] The outer ring 131 is, e.g., a divided outer ring, and is provided with a pair of outer ring divided pieces 135, 136 that are coaxially fastened in the axial direction. In the present example, the first teeth 23 of the rigid gear 2A are formed on the end surface of the outer ring divided piece 135 that contacts the end surface of the housing 110. Specifically, the rigid gear 2A is integrated with the outer ring divided piece 135, and the two are produced as a single component. It is also possible to use a cross-roller bearing having a configuration provided with a cylindrical roller insertion hole (insertion groove) in the outer ring or the inner ring instead of using a divided outer ring 131. Due to the cross-roller bearing 130, the rigid gear 2A that is secured to the housing 110, which is a fixed-side member, and the flexible gear 3A that is secured to the rotary output shaft 120 are retained in a state that allows relative rotation.

[0039] An annular end plate portion 111 extending radially inward is formed on the other end of the housing 110. The end plate portion 111 faces the rigid cam plate 41 of the wave generator 4A in the axial direction. The thrust roller bearings 140 are mounted between the end plate portion 111 and the rigid cam plate 41.

[0040] In the unit-type flat strain wave gearing 100 having the configuration described above, for example, a motor output shaft (not shown) is coaxially linked to the rigid cam plate 41 of the wave generator 4A. There may be cases where an ultrasonic motor is applied as a linked drive motor in order to impart pre-pressure to the wave generator 4A in the axial direction.

Claims

1. A flat strain wave gearing (1; 100) comprising:

a rigid gear (2; 2A) that has an end surface (22) perpendicular to an axial direction (1a), and first teeth (23) formed on the end surface (22) at a uniform pitch in a circumferential direction;
a flexible gear (3; 3A) that faces the rigid gear (2; 2A) in the axial direction (1a), and second teeth

(35) formed at a uniform pitch in the circumferential direction, the second teeth (35) meshing with the first teeth (23) in the axial direction (1a); and

a wave generator (4; 4A) that causes a tooth formation portion (34) of the flexible gear (3; 3A) where the second teeth (35) are formed to flex in the axial direction (1a), the second teeth (35) to mesh with the first teeth (23) at a plurality of positions set apart in the circumferential direction, and the positions where the two gears (2, 3) mesh to move in the circumferential direction, wherein the flexible gear (3; 3A) is formed in a shape that follows a flat truncated-cone shape having a vertex angle of at least 165° and less than 180°, and wherein the flexible gear (3; 3A) is provided with:

a rigid boss (31);
a diaphragm (32) that has a bellows-form cross-section, the diaphragm (32) expanding from an outer peripheral edge of the rigid boss (31) outward and toward a direction away from the rigid gear (2; 2A); and
a conical barrel part (33) that is continuous with an outer peripheral edge of the diaphragm (32) and expands outward and toward a direction away from the rigid gear (2; 2A),
the tooth formation portion (34) being formed on the conical barrel part (33) wherein the wave generator (4; 4A) has:

a rigid cam plate (41) formed with a cam surface (45) that functions as a roller raceway surface (45) facing an inner peripheral surface of the tooth formation portion (34) of the conical barrel part (33) in the axial direction;
a plurality of cylindrical rollers (42; 134) that are mounted between the cam surface (45) of the rigid cam plate (41) and the inner peripheral surface of the flexible gear (3; 3A); and
an annular retainer (43) that retains the plurality of cylindrical rollers (42; 134) at uniform intervals in the circumferential direction, and wherein a curved shape of the cam surface (45) in the circumferential direction is regulated such that a position in the axial direction (1a) of the plurality of cylindrical rollers (42; 134), which roll in the circumferential direction on the cam surface (45), undulates a plurality of times at uniform amplitude in the axial direction (1a) while the plurality of cylindrical rollers (42; 134) complete

one cycle along the cam surface (45);

characterized in that

the retainer (43) of the wave generator (4; 4A) has flexibility in the axial direction (1a);

the retainer (43) consists of a plurality of modules (46) being linked in the circumferential direction, and each module (46) is linked to the modules (46) adjacent thereto in a rotatable state relative to the adjacent modules (46) about a radius line passing through a center of the retainer (43).

2. The flat strain wave gearing (1; 100) according to claim 1, wherein the cam surface (45) is a curved surface that is perpendicular to the axial direction (1a).

3. The flat strain wave gearing (1; 100) according to claim 1, wherein

a cam surface (45) is defined by a curve that emulates a shape of the inner peripheral surface of the tooth formation portion (34), the shape being obtained in a flexed state in which the tooth formation portion (34) of the flexible gear (3; 3A) is flexed in the axial direction, and the flexed state of the tooth formation portion (34) is a state in which the tooth formation portion (34) is flexed in the axial direction by a maximum displacement amount at a plurality of positions in the circumferential direction, where the maximum displacement amount is a displacement amount in the axial direction that is required for the second teeth (35) of the flexible gear (3; 3A) to mesh with the first teeth (23) of the rigid gear (2; 2A).

4. The flat strain wave gearing (1; 100) according to claim 1, further comprising:

a cylindrical housing (6; 110) in which the rigid gear (2; 2A), the flexible gear (3; 3A), and the wave generator (4; 4A) are assembled; an output shaft (8; 120) coaxially fixed to the rigid boss (31) of the flexible gear (3; 3A); a first bearing (130) that is disposed between the housing (6; 110) and the output shaft (8; 120) and that supports the output shaft (8; 120) in a state that allows rotation with respect to the housing (6; 110); and a second bearing (140) that is disposed between the housing (6; 110) and the rigid cam plate (41) of the wave generator (4; 4A) and that supports the rigid cam plate (41) in the axial direction (1a) in a state that allows rotation with respect to the

housing (6; 110).

5. The flat strain wave gearing (1; 100) according to claim 4, wherein the first bearing (130) has:

an outer-ring raceway surface (132) formed on a circular inner peripheral surface of the rigid gear (2; 2A) that is fixed coaxially to the housing; an inner-ring raceway surface (133) formed on a circular outer peripheral surface of the output shaft (8; 120); and rolling elements (134) that are accommodated in a rollable state between the outer-ring raceway surface (132) and the inner-ring raceway surface (133).

Patentansprüche

1. Flaches Verformungswellgetriebe (1; 100), das Folgendes aufweist:

ein steifes Zahnrad (2; 2A), das eine Stirnfläche (22) rechtwinklig zu einer axialen Richtung (1a) besitzt und erste Zähne (23) aufweist, die auf der Stirnfläche (22) in einer gleichmäßigen Beabstandung in Umfangsrichtung ausgebildet sind;

ein flexibles Zahnrad (3; 3A), das dem steifen Zahnrad (2; 2A) in der axialen Richtung (1a) zugewandt gegenüberliegend angeordnet ist, und zweite Zähne (35) aufweist, die in einer gleichmäßigen Beabstandung in der Umfangsrichtung ausgebildet sind, wobei die zweiten Zähne (35) mit den ersten Zähnen (23) in der axialen Richtung (1a) kämmen; und einen Wellgenerator (4; 4A), der einen Verzahnungsbereich (34) des flexiblen Zahnrads (3; 3A), in dem die zweiten Zähne (35) ausgebildet sind, zu einer Biegung in der axialen Richtung (1a) veranlasst, so dass die zweiten Zähne (35) mit den ersten Zähnen (23) an einer Mehrzahl von in der Umfangsrichtung voneinander beabstandeten Positionen kämmen, und die Positionen, an den die beiden Zahnräder (2, 3) in Kämmeingriff stehen, sich in der Umfangsrichtung bewegen, wobei das flexible Zahnrad (3; 3A) in einer Form ausgebildet ist, die einer flachen Kegelstumpfform folgt, die einen Scheitelwinkel von mindestens 165° und weniger als 180° aufweist, und wobei das flexible Zahnrad (3; 3A) aufweist:

eine steife Nabe (31); eine Membran (32), die einen balgförmigen Querschnitt aufweist, wobei sich die Membran (32) von einem Außenumfangsrand der

- steifen Nabe (31) nach außen und in Richtung von dem steifen Zahnrad (2; 2A) weg erstreckt; und
 ein konisches Hülsenteil (33), das an einen Außenumfangsrand der Membran (32) anschließt und sich nach außen sowie in Richtung von dem steifen Zahnrad (2; 2A) weg ausbreitet,
 wobei der Verzahnungsbereich (34) an dem konischen Hülsenteil (33) ausgebildet ist, wobei der Wellgenerator (4; 4A) aufweist: eine steife Steuerflächenplatte (41), die mit einer Steuerfläche (45) ausgebildet ist, die als Rollenlaufbahnfläche (45) wirkt, die einer Innenumfangsfläche des Verzahnungsbereichs (34) des konischen Hülsenteils (33) in der axialen Richtung zugewandt gegenüberliegend angeordnet ist;
 eine Mehrzahl von zylindrischen Rollen (42; 134), die zwischen der Steuerfläche (45) der steifen Steuerflächenplatte (41) und der Innenumfangsfläche des flexiblen Zahnrads (3; 3A) angebracht sind; und
 einen ringförmigen Halter (43), der die Mehrzahl der zylindrischen Rollen (42; 134) in gleichmäßigen Abständen in der Umfangsrichtung hält, und
 wobei eine gekrümmte Form der Steuerfläche (45) in der Umfangsrichtung derart geregelt ist, dass eine Position in der axialen Richtung (1a) der Mehrzahl der zylindrischen Rollen (42; 134), die in der Umfangsrichtung auf der Steuerfläche (45) rollen, eine Mehrzahl von Malen Wellbewegungen mit gleichmäßiger Amplitude in der axialen Richtung (1a) ausführt, während die Mehrzahl der zylindrischen Rollen (42; 134) einen Zyklus entlang der Steuerfläche (45) vollständig ausführt,
dadurch gekennzeichnet,
dass der Halter (43) des Wellgenerators (4; 4A) Flexibilität in der axialen Richtung (1a) aufweist;
dass der Halter (43) aus einer Mehrzahl von Modulen (46) besteht, die in der Umfangsrichtung gekoppelt sind, und
dass jedes Modul (46) mit den diesem benachbarten Modulen (46) in einem Zustand gekoppelt ist, in dem es relativ zu den benachbarten Modulen (46) um eine Radiuslinie drehbar ist, die durch eine Mitte des Halters (43) verläuft.
2. Flaches Verformungswellgetriebe (1; 100) nach Anspruch 1,
 wobei die Steuerfläche (45) eine gekrümmte Fläche ist, die rechtwinklig zu der axialen Richtung (1a) ist.

3. Flaches Verformungswellgetriebe (1; 100) nach Anspruch 1,

wobei eine Steuerfläche (45) durch eine Kurve definiert ist, die eine Form der Innenumfangsfläche des Verzahnungsbereichs (34) emuliert, wobei die Form in einem gebogenen Zustand erhalten wird, in dem der Verzahnungsbereich (34) des flexiblen Zahnrads (3; 3A) in der axialen Richtung gebogen wird, und wobei der gebogene Zustand des Verzahnungsbereichs (34) ein Zustand ist, in dem der Verzahnungsbereich (34) an mehreren Positionen in der Umfangsrichtung in der axialen Richtung um einen maximalen Verschiebungsbetrag gebogen ist, wobei der maximale Verschiebungsbetrag ein Verschiebungsbetrag in der axialen Richtung ist, der für die zweiten Zähne (35) des flexiblen Zahnrads (3; 3A) erforderlich ist, um mit den ersten Zähnen (23) des steifen Zahnrads (2; 2A) in Kämmeingriff zu gelangen.

4. Flaches Verformungswellgetriebe (1; 100) nach Anspruch 1,
 das weiterhin aufweist:

ein zylindrisches Gehäuse (6; 110), in dem das steife Zahnrad (2; 2A), das flexible Zahnrad (3; 3A) und der Wellgenerator (4; 4A) montiert sind;
 eine Ausgangswelle (8; 12), die an der steifen Nabe (31) des flexiblen Zahnrads (3; 3A) koaxial befestigt ist;
 ein erstes Lager (130), das zwischen dem Gehäuse (6; 110) und der Ausgangswelle (8; 12) angeordnet ist und das die Ausgangswelle (8; 120) in einem Zustand abstützt, der eine Drehung in Bezug auf das Gehäuse (6; 110) zulässt; und
 ein zweites Lager (140), das zwischen dem Gehäuse (6; 110) und der steifen Steuerflächenplatte (41) des Wellgenerators (4; 4A) angeordnet ist und das die steife Steuerflächenplatte (41) in der axialen Richtung (1a) in einem Zustand abstützt, der eine Drehung in Bezug auf das Gehäuse (6; 110) zulässt.

5. Flaches Verformungswellgetriebe (1; 100) nach Anspruch 4,
 wobei das erste Lager (130) aufweist:

eine Außenring-Laufbahnfläche (132), die auf einer kreisförmigen Innenumfangsfläche des steifen Zahnrads (2; 2A) ausgebildet ist, das an dem Gehäuse koaxial befestigt ist;
 eine Innenring-Laufbahnfläche (133), die auf einer kreisförmigen Außenumfangsfläche der Ausgangswelle (8; 120) ausgebildet ist; und
 Wälzkörper (134), die in einem rollfähigen Zu-

stand zwischen der Außenring-Laufbahnfläche (132) und der Innenring-Laufbahnfläche (133) aufgenommen sind.

Revendications

1. Dispositif d'engrenages à ondes de déformation plat (1 ; 100) comprenant :

un engrenage rigide (2 ; 2A) qui présente une surface d'extrémité (22) perpendiculaire à une direction axiale (1a) et des premières dents (23) formées sur la surface d'extrémité (22) selon un pas uniforme dans une direction circonférentielle ;
un engrenage souple (3 ; 3A) qui fait face à l'engrenage rigide (2 ; 2A) dans la direction axiale (1a) et des deuxièmes dents (35) formées selon un pas uniforme dans la direction circonférentielle, les deuxièmes dents (35) s'engrenant avec les premières dents (23) dans la direction axiale (1a) ; et
un générateur d'ondes (4 ; 4A) qui fait en sorte qu'une partie de formation de dents (34) de l'engrenage souple (3 ; 3A) où sont formées les deuxièmes dents (35) fléchisse dans la direction axiale (1a), que les deuxièmes dents (35) s'engrènent avec les premières dents (23) en une pluralité de positions distinctes dans la direction circonférentielle, et que les positions où les deux engrenages (2, 3) s'engrènent se déplacent dans la direction circonférentielle, l'engrenage souple (3 ; 3A) étant conçu dans une forme qui suit celle d'un cône tronqué plat ayant un angle de sommet d'au moins 165° et de moins de 180°, et
l'engrenage souple (3 ; 3A) étant pourvu :

d'une protubérance rigide (31) ;
d'un diaphragme (32) ayant une section transversale en forme de soufflet, le diaphragme (32) se dilatant à partir d'un bord périphérique extérieur de la protubérance rigide (31) vers l'extérieur et dans une direction opposée à l'engrenage rigide (2 ; 2A) ; et
d'une pièce conique (33) qui est en continuité avec un bord périphérique extérieur du diaphragme (32) et qui s'étend vers l'extérieur et dans une direction opposée à l'engrenage rigide (2 ; 2A), la partie de formation de dents (34) étant réalisée sur la pièce conique (33) dans lequel le générateur d'ondes (4 ; 4A) présente :

une plaque de came rigide (41) formée

avec une surface de came (45) qui fonctionne comme une surface de chemin de roulement de rouleaux (45) faisant face à une surface périphérique intérieure de la partie de formation de dents (34) de la pièce conique (33) dans la direction axiale ;
une pluralité de rouleaux cylindriques (42 ; 134) qui sont montés entre la surface de came (45) de la plaque de came rigide (41) et la surface périphérique intérieure de l'engrenage souple (3 ; 3A) ; et
un dispositif de retenue annulaire (43) qui retient la pluralité de rouleaux cylindriques (42 ; 134) à des intervalles uniformes dans la direction circonférentielle, et
dans lequel une forme incurvée de la surface de came (45) dans la direction circonférentielle est réglée de telle sorte qu'une position dans la direction axiale (1a) de la pluralité de rouleaux cylindriques (42 ; 134), qui roulent dans la direction circonférentielle sur la surface de came (45), ondule plusieurs fois à une amplitude uniforme dans la direction axiale (1a) pendant que la pluralité de rouleaux cylindriques (42 ; 134) accomplit un cycle le long de la surface de came (45) ;

caractérisé en ce que

le dispositif de retenue (43) du générateur d'ondes (4 ; 4A) a une souplesse dans la direction axiale (1a) ;
le dispositif de retenue (43) consiste en une pluralité de modules (46) étant reliés dans la direction circonférentielle, et
chaque module (46) est relié aux modules (46) adjacents dans un état rotatif par rapport aux modules adjacents (46) autour d'une ligne de rayon passant par le centre du dispositif de retenue (43).

2. Le dispositif d'engrenages à ondes de déformation plat (1 ; 100) selon la revendication 1, dans lequel la surface de came (45) est une surface incurvée qui est perpendiculaire à la direction axiale (1a).
3. Le dispositif d'engrenages à ondes de déformation plat (1 ; 100) selon la revendication 1, dans lequel

une surface de came (45) est définie par une courbe qui émule une forme de la surface périphérique intérieure de la partie de formation de

dents (34), la forme étant obtenue dans un état fléchi dans lequel la partie de formation de dents (34) de l'engrenage souple (3 ; 3A) est fléchie dans la direction axiale, et l'état fléchi de la partie de formation de dents (34) est un état dans lequel la partie de formation de dents (34) est fléchie dans la direction axiale selon une quantité de déplacement maximale en une pluralité de positions dans la direction circonférentielle, la quantité de déplacement maximale étant une quantité de déplacement dans la direction axiale qui est nécessaire pour que les deuxièmes dents (35) de l'engrenage souple (3 ; 3A) s'engrènent avec les premières dents (23) de l'engrenage rigide (2 ; 2A).

4. Le dispositif d'engrenages à ondes de déformation plat (1 ; 100) selon la revendication 1, comprenant en outre :

un boîtier cylindrique (6 ; 110) dans lequel sont assemblés l'engrenage rigide (2 ; 2A), l'engrenage souple (3 ; 3A) et le générateur d'ondes (4 ; 4A) ;
un arbre de sortie (8 ; 120) fixé coaxialement à la protubérance rigide (31) de l'engrenage souple (3 ; 3A) ;
un premier palier (130) qui est disposé entre le boîtier (6 ; 110) et l'arbre de sortie (8 ; 120) et qui supporte l'arbre de sortie (8 ; 120) dans un état qui permet la rotation par rapport au boîtier (6 ; 110) ; et
un deuxième palier (140) qui est disposé entre le boîtier (6 ; 110) et la plaque de came rigide (41) du générateur d'ondes (4 ; 4A) et qui supporte la plaque de came rigide (41) dans la direction axiale (1a) dans un état qui permet la rotation par rapport au boîtier (6 ; 110).

5. Le dispositif d'engrenages à ondes de déformation plat (1 ; 100) selon la revendication 4, dans lequel le premier palier (130) présente :

une surface de chemin de roulement annulaire extérieure (132) formée sur une surface périphérique intérieure circulaire de l'engrenage rigide (2 ; 2A) qui est fixée coaxialement au boîtier ;
une surface de chemin de roulement annulaire intérieure (133) formée sur une surface périphérique extérieure circulaire de l'arbre de sortie (8 ; 120) ; et
des éléments roulants (134) qui sont logés dans un état roulant entre la surface de chemin de roulement annulaire extérieure (132) et la surface de chemin de roulement annulaire intérieure (133).

FIG. 1

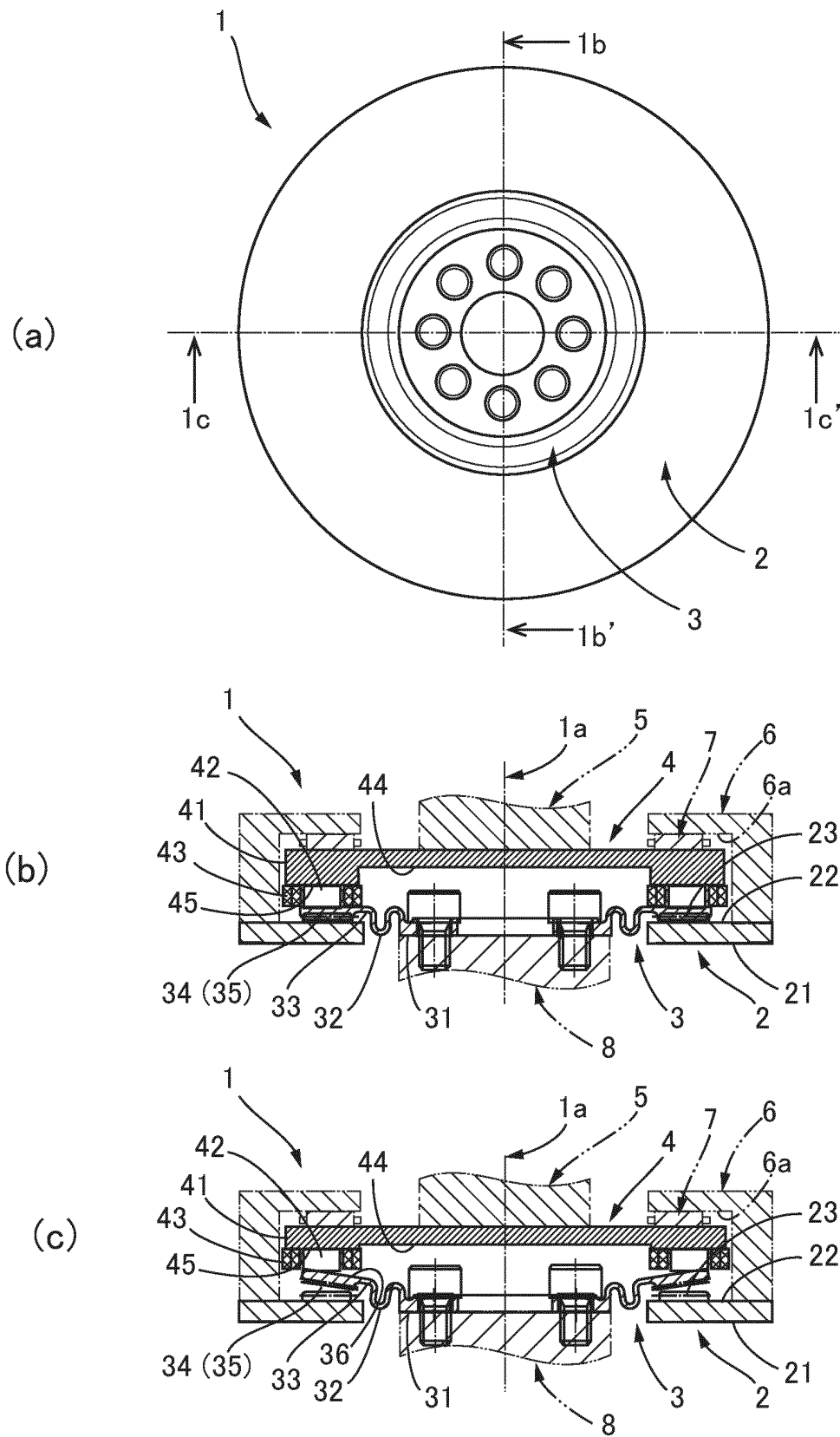


FIG. 2

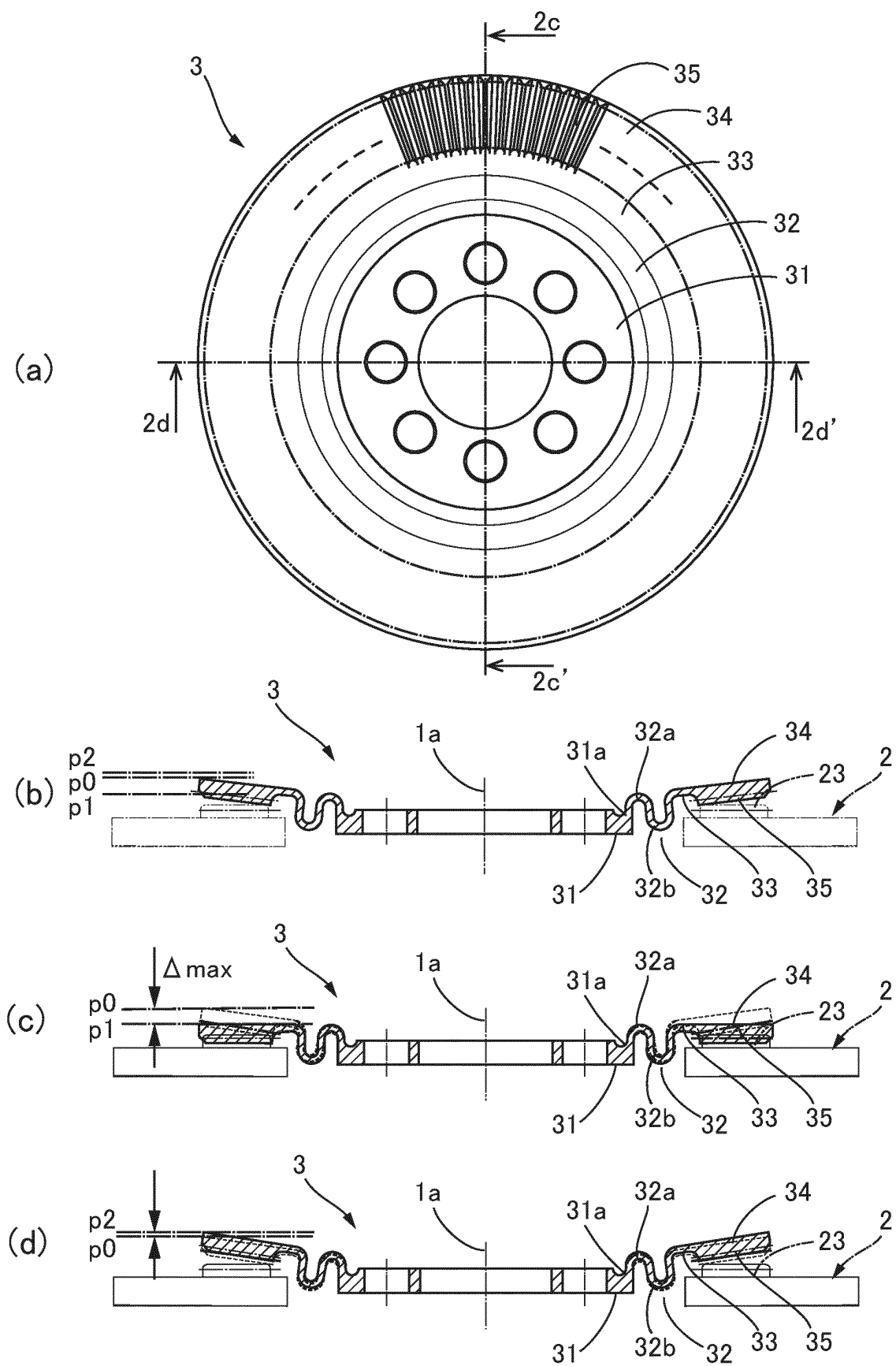


FIG. 3

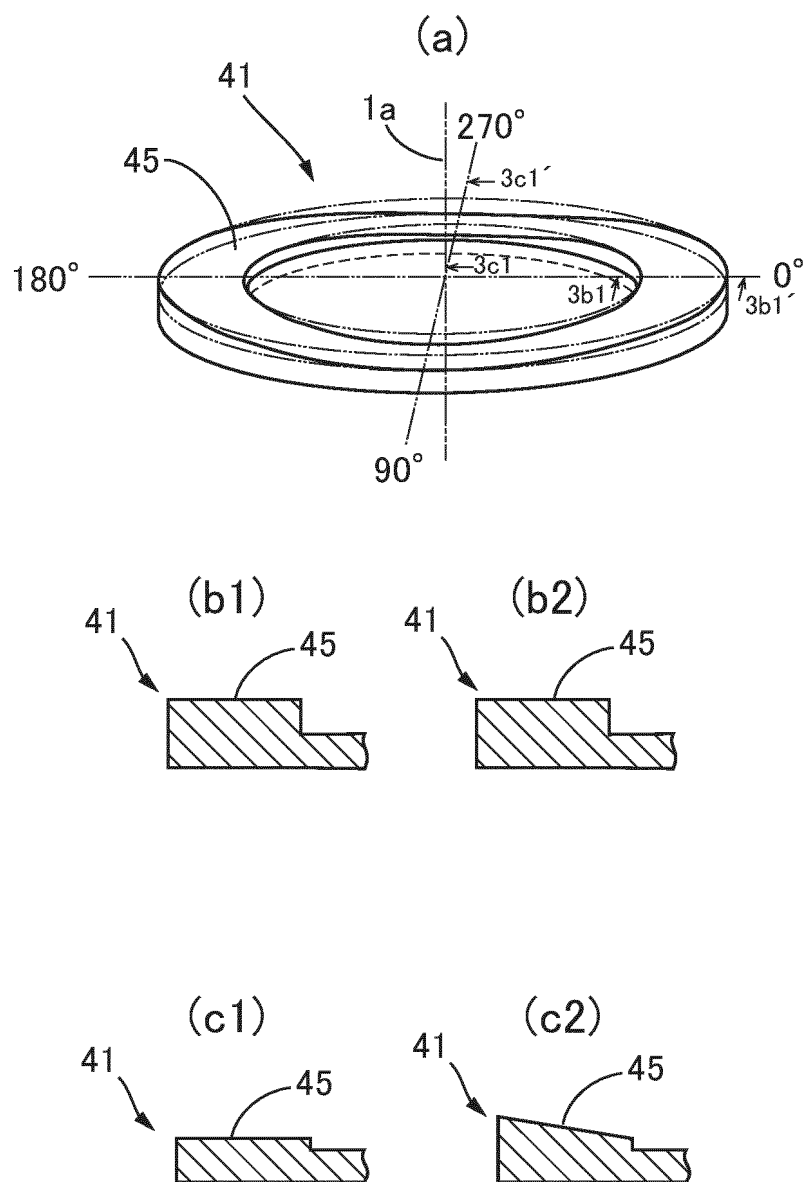


FIG. 4

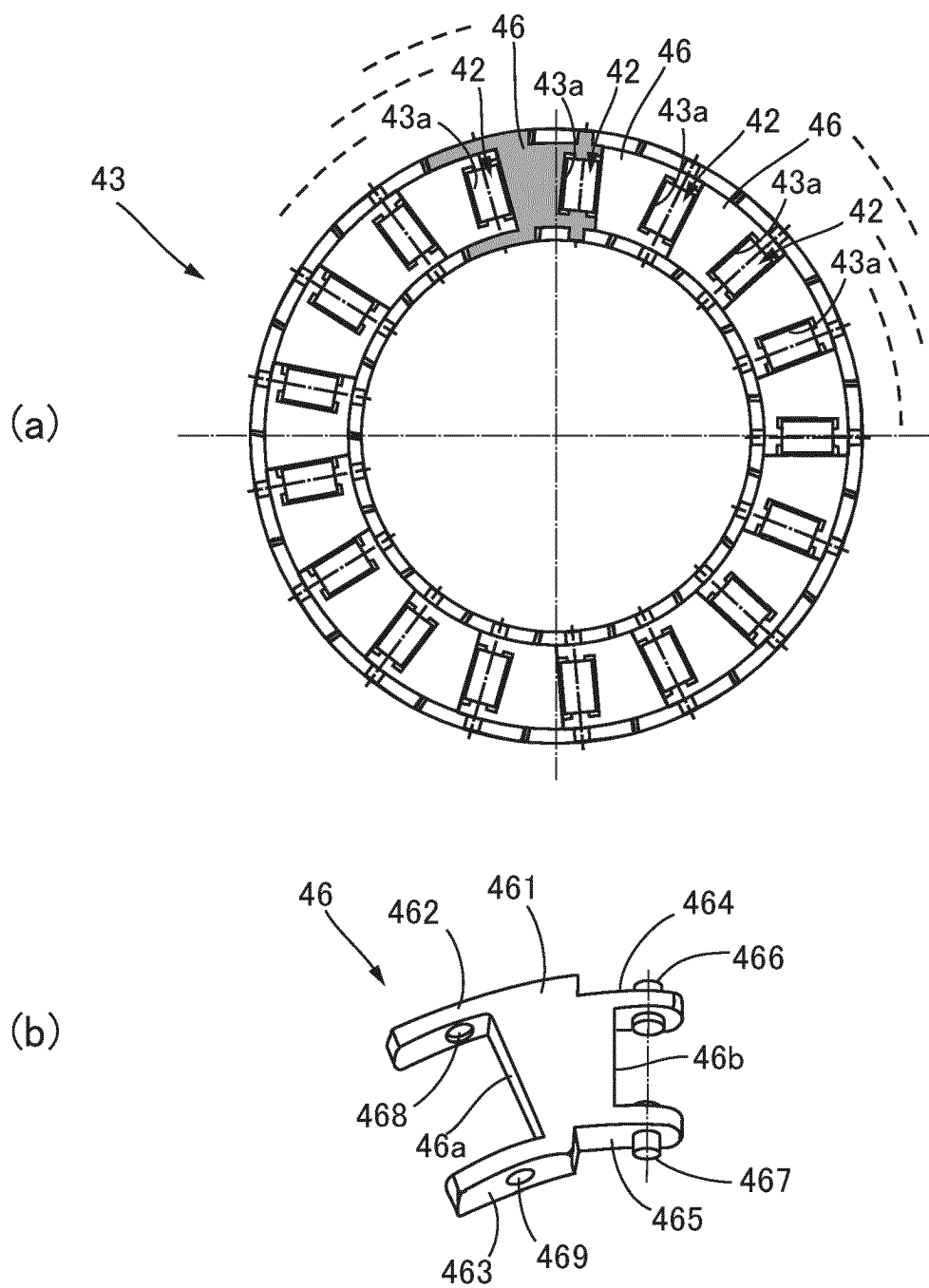


FIG. 5

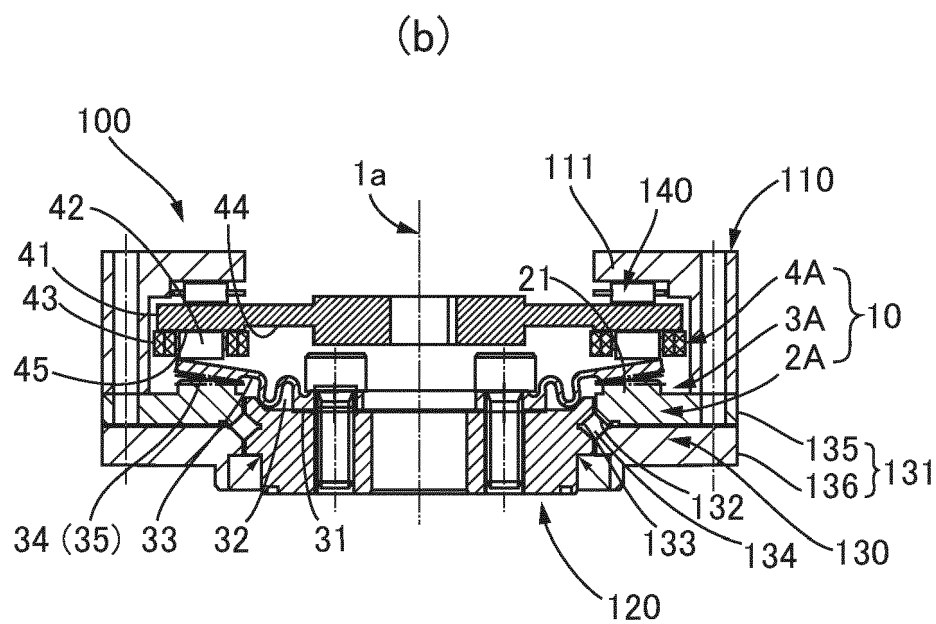
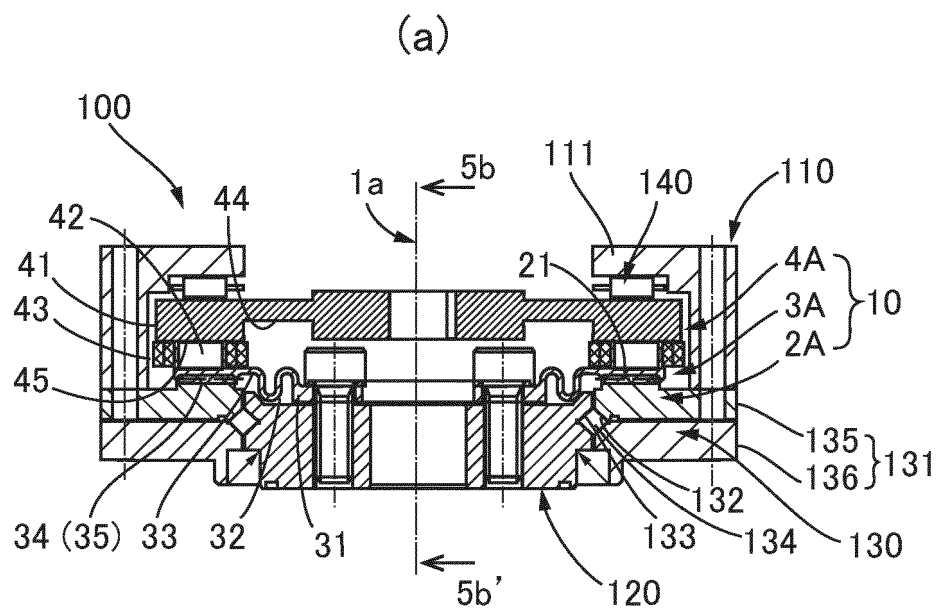
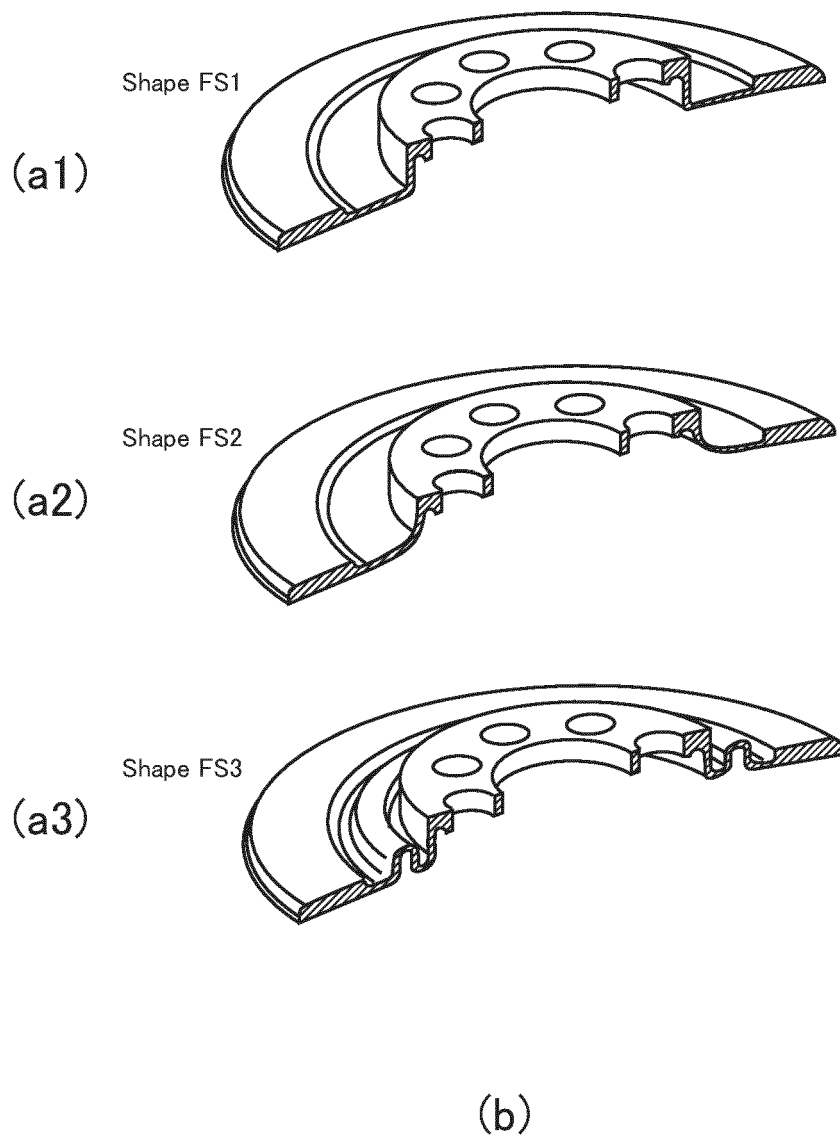


FIG. 6



Shape of Diaphragm	Displacement Reaction Force	Maximum Stress	Displacement Amount		
			Displacement Amount 1	Ratio = Displacement 2 / Displacement 1	Total of Displacement Amounts
Shape 1	1.00	1.00	1.00	1.5 %	1.00
Shape 2	2.45	1.27	1.00	13.1 %	1.11
Shape 3	1.66	1.03	1.00	27.3 %	1.25

REFERENCES CITED IN THE DESCRIPTION

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